(54) Method and apparatus for recording and replay of digital audio data.

(57) For both recording and replay, a digital audio tape (14) is accelerated very rapidly by a motor servo (9), motor (8) and capstan (7) so that the tape speed overshoots nominal speed range before settling back to this range in an oscillatory manner. The digital samples are recorded and replayed via a head (15), a random access memory (17) and input/output electronics (19). During recording, the store (17) is precharged by starting to write in as soon as acceleration is initiated. Readout to the tape is initiated as soon as the tape first reaches the nominal speed range. Uniformity of samples as recorded on the tape is preserved by clocking a read address generator (21) at a rate proportional to tape speed, signaled by a tachometer (7). The write address generator is clocked at the constant sampling rate. For replay the write address generator is clocked at the tape speed rate while the read address generator (21) is clocked at the constant sample rate. Write in and read out are both initiated when the tape speed first reaches the nominal range. The addresses provided by the generators (20 and 21) are compared by a comparator (22) which provides a reference signal to the servo (9) in an arrangement such as to adjust the tape speed always in the sense to maintain a constant degree of filling of the store (17).
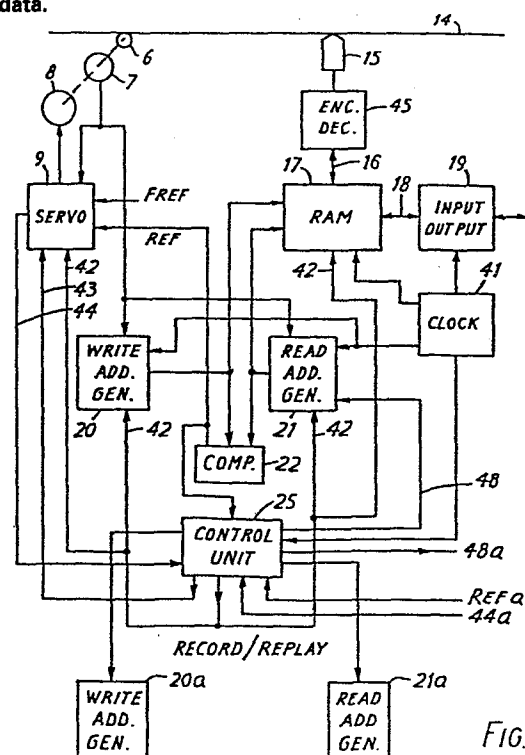
FIG.6

METHOD AND APPARATUS FOR RECORDING
AND REPLAY OF DIGITAL AUDIO DATA

This invention relates to a method for recording and
replay of digital audio data on magnetic tape and to apparatus
for carrying out this method.

The quality of recording and replay with digital audio is
5   very sensitive to variations in tape speed. Since the speed is
inevitably not absolutely constant, we define the nominal speed
of the tape as that mean speed for which the accumulated speed
variations over the time of operation of the tape equal zero.
In the present state of the art, these speed variations are
10   compensated for by time base correction, which uses a very small
buffer memory, only capable of storing and subsequently releasing
data in order to transform the not absolutely regular data output
from the tape to an absolutely regular one. In practice the tape
runs within a nominal speed range about the exact nominal speed and
15   the small residual fluctuations of the speed are confined to that
speed range.

In a conventional start-up operation, the tape is
accelerated from zero speed to its nominal speed range in a
certain and finite time. Until the tape stabilises to its nominal
20   speed range, correct recording and replay of the samples
representing the digital audio data is not possible. This is
because the velocity of the tape is varying and does not always
correspond to the actual sampling rate. The condition for
accurate recording is to have a   uniform distribution
25   of samples on the tape. For replay, the condition is that the
samples have to reach the audio electronics at a rate
corresponding to the nominal speed range. Since these conditions
are not met during start-up operations, the correct recording or
replay only starts when tape has stabilised to its nominal
30   velocity range.

Synchronising two digital recorders with great accuracy
using the conventional techniques of analogue recorders is slow
and locking to common clocks brings an additional uncertainty.
Synchronising two analogue audio tape machines is in practice

achieved by adjusting the tape-speed of a second tape machine to the tape speed of a first tape machine. As the tape speed is not perfectly constant, this means that the tape speed of the second tape machine follows the tape speed of the first tape machine, but with alternately positive and negative differences.

The synchronisation of two digital tape machines is different in that the tape speed of both tape machines is to be synchronised to a common time reference. There may then remain a certain phase-difference between the two tapes. This may mean that corresponding digital audio samples are not recorded or replayed at the same time. At present the techniques for synchronising digital audio on magnetic tape are not satisfactory and perfect synchronisation is not possible.

The object of the present invention as defined in the claims is therefore to provide a method for recording and replay of digital audio data on magnetic tape which permits fast start-up and synchronisation, together with apparatus for performing this method.

Using the invented method, a much faster start-up is possible. This means that correct recording and replay of digital audio data is reached in a much shorter time after starting the tape machines. The method also allows fast synchronisation between two or more tape machines. In addition this synchronisation is very simple to obtain and failure of synchonism is most improbable. As this invénted method operates with a store, the usual Time Base Correction circuitry may be omitted by incorporating its functions into that of the store.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figures 1 and 2 show variations of tape speed during start-up,

Figure 3 shows variations of tape speed of two tape machines to be synchronised,

Figure 4 shows distances covered by two synchronised tapes after different times,

Figure 5 shows the difference of the distances according to figure 4, and

Figure 6 is a block diagram of the apparatus embodying
the invention.

In Figure 1, the vertical axis of the diagram represents
the speed of a tape driven in a well known manner. The horizontal
axis represents time. Conventionally, the speed of a tape during
start-up operations commencing at time t_o has a profile similar
to the dotted line 3. During a start-up operation making use of
the invented method, the speed may have a profile similar to line 4.
In both cases, the speed has ultimately to reach a nominal speed
range 5. Whereas with conventional techniques, correct recording
or replay can only begin when the tape speed stabilises to the
nominal range 5 at time t_2, the invented method allows correct
recording or replay to begin as soon as the tape approaches the
nominal speed at time t_1. Therefore, it is advantageous with the
invented method that a speed profile similar to 4 be followed
since the nominal speed range 5 is first reached after a time
T_1: it takes an additional time T_3 to stabilize to the nominal
speed range 5. In conventional operation, it takes the tape a
time T_2 added to the time T_1 to reach the nominal speed range 5.

Figure 2 shows a diagram similiar to Fig 1, but here
the speed 11 of the tape approaches the nominal speed range 5a in
the manner of a damped oscillation.

In a similar diagram, Figure 3 shows two slightly different
speed profiles 12 and 13 of two similar tape machines accelerating
their respective tapes from zero to a common nominal speed range 5.
In Figure 4, distances covered by a specific tape-element after
accelerating according to the speed profiles of Figure 3 are shown.
Curves 28 and 29 indicate distances covered by the two separate
tapes on two tape machines. Line 30 indicates the distance covered
by a third tape with theoretical immediate acceleration up to
nominal speed.

In Figure 5, the curve 32 shows the difference between
the distances covered by the two tapes and it is apparent that
the difference stabilizes when acceleration of the tapes has ended.

Figure 6 is a block diagram of an apparatus for recording
on and for replay from magnetic tape 14. This apparatus comprises
a tape machine well known and belonging to the state of the art.
The machine is represented by a record and replay head 15, a

capstan 6, a tachometer 7, a motor 8 and a servo 9 for controlling
the motor 8. In practice there will almost certainly be separate
replay and recording heads but a combined head is shown for
simplicity of description of both recording and replay operations.
The head 15 is connected by a line 16 to a RAM store 17 via an
encoder/decoder unit 45. In recording, this unit works as an
encoder and translates the incoming data into a format suitable for
recording. In replay it performs the inverse operation as a
decoder. The store 17 can be implemented using solid state RAMs
with a fixed timing locked to the desired sampling frequency and
several read and write cycles per sampling interval to accommodate
fluctuations in the incoming data rate, as well as several read
cycles for ease of processing. The necessary circuits are well
known in state of the art digital audio. The store 17 is connected
by means of one or more lines 18 to the usual input-output
electronics 19.

All operations are synchronised by a master clock 41 which
establishes the sampling interval in the input-output electronics
19 and the read-write cycle of the store 17.

The store 17 is provided with a write address generator 20
and a read address generator 21. Each of these generators can be
clocked in well known manner to step cyclically through the
addresses of the store 17 and each has provision to select between
clocking by the clock 41 and the tachometer 7. This selection is
made by a control unit 25 which, among other things, selects
between record and replay modes.

The read addresses follow the write addresses and the offset
between the read and write addresses represents the degree to which
the store 17 is filled. A comparator 22 determines the said
offset and provides a reference signal REF to the motor servo 9
which also has available a fixed reference FREF corresponding to
the nominal tape speed.

The operation of the apparatus when stable running has been
achieved will firstly be considered. During recording the write
address generator 20 is clocked by the clock 41 at the sample
rate, whereas the read address generator 21 is clocked by the
tachometer 7 so that the samples are fed to the recording head 15

at a rate proportional to tape speed and are recorded at constant pitch (spacing), notwithstanding fluctuations in tape speed. The lines 16 and 18 are switched to the output and input buses of the store 17 respectively. Conversely, during replay, the lines 16 and 18 are switched to the input and output buses, the write address generator 20 is clocked by the tachometer 7 and the read address generator 21 is clocked by the clock 41. The switching of these various functions is controlled by a RECORD/ REPLAY mode line 42 from the control unit 25.

The motor servo 9 compares the tachometer signal with the REF signal from the comparator 22 and adjusts the instantaneous tape speed so as to maintain a certain degree of fill of the store 17. The servo 9 has to respond oppositely to errors in the two modes and is therefore also switched by the RECORD/REPLY line 42. During recording, if the store 17 gets over-full, the tape 14 is speeded up. During replay, if the store 17 gets overfull, the tape 14 is slowed down. During replay, precise timing of the write address generator 20 may be controlled by a clock signal also replayed from the tape 14. Such a signal can be used instead of the tachometer signal.

During start-up conditions, the control unit 25 provides a signal on line 43 to the motor servo 9 to cause it to drive the tape up to speed in accordance with curve 4 of Fig 1 or curve 11 of Fig 2. This may be achieved in various ways, such as by use of a predetermined forcing function or by switching from use of REF to FREF and allowing the servo to act with very little damping.

Accordingly, for a fast start-up, the tape drive is started and the speed of the tape is increased as rapidly as possible, consistent with accurate replay of data from the tape.

For recording, the data samples are transferred from the input/ output electronics 19 through line 18 into the store 17. Accordingly the store 17 is filling-up with data from the input/ output electronics 19 at the constant rate. When the tape speed approaches its nominal speed range 5, that is approximately at time t_1, the tape speed motor servo 9 emits a signal on line 44 to the control unit 25 which, in turn, starts the read address

generator 21. This provides addresses starting with the memory
location which contains the first digital audio sample to be
output from the store 17. These output signals leave the store
17 at a rate corresponding to the current tape speed and are
5   directed through line 16 to the recording head 15. Since the tape
speed continues to vary after time t_1, the output data rate is
varied to conform to the tape speed, in the manner already described.

As the tape speed reaches higher values than the nominal
speed range 5, the store 17 depletes more quickly than it receives
10 new data. This situation remains during time T_2, which means that
the store 17 has to be precharged with data samples corresponding
to the area 33 in Fig 1 or area 34 in Fig 2 contained between t_1
and t_2. This data is loaded into the store for a period before
time t_1 and the store should be large enough to accommodate it.
15 Once the tape speed has stabilised to the nominal speed range 5,
that is after time t_3 (Fig 1) or time t_4 (Fig 2), the tape
speed is controlled by the comparator 22 and the motor servo 9,
as described above. They ensure that, on average, the difference
between the read and write addresses remains constant and hence
20 that the average recording rate corresponds exactly to the audio
data rate.

As described, the switching of the read address generator
21 at t_1, i.e. the initiation of the actual recording on tape,
takes place in dependence upon monitored tape speed. It may also
25 be possible to effect the switching a fixed time T_1 after t_o.
This time may even be shortened to start actual recording a
little before t_1. Similarly the switching of the servo 9 from
start-up mode to normal mode at t_3 or t_4 may be effected after
elapse of a preset time or it may be effected when the tape speed
30 signal from the tachometer 7 or from a clock track on the tape
ceases to fluctuate beyond the range 5. This may be tested by
measuring the tape speed fluctuations and checking if these
lie within tolerance.

For replay, data contained on the tape 14 are transferred
35 from the replay head 15 through the line 16 to the store 17.
When the tape speed first approaches the nominal range 5, i.e.
around t_1, the servo 9 signals the control unit 25 to instruct
the write address generator 20 to start writing data into the

store. Since the tape speed is varying, the rate at which data
is written is varied to conform to the tape speed, as described
above. Also at time t_1 or shortly thereafter, the read address
generator 21 is told by the unit 25 to start providing addresses

5   to the memory locations which contain samples to be output from
the store 17. These are directed through line 18 to the input/
output electronics 19. This apparatus operates therefore in a
similar way for recording and for replay. As before, once the
tape speed has stabilised to its nominal value, it is controlled

10   by the comparator 22 and servo 9.

Fast synchronisation of two digital tape machines can be
achieved by employing the fast start up techniques just
described. We assume as an example that both tapes on the tape
machines reach their nominal speed range 5 as shown in Fig 3. If

15   we look at two corresponding samples, one on each tape, before
start-up at t_o and we follow them through the acceleration of the
tapes represented by the lines 28 and 29 we find them again at
a distance 47 at time t_1 and a similar distance 38 at time t_3. If
both stores 17 of both tape machines have now stored data from the

20   times that the nominal tape speed is reached, the store 17 of the
machine with the greater acceleration will be more full than the
store of the other machine. This difference of data has to be
corrected in order to synchronise the corresponding audio
data streams.

25   Each tape machine to be synchronised contains essentially
the apparatus shown in Fig 6. When both machines first reach
approximately nominal speed, it is then possible with the invented
method immediately to synchronise the two machines. At this point,
data from the tape is being written into the store 17 of each

30   machine and regular output data may be read from each store as
described earlier for the replay mode. However, since the two
tapes will have accelerated in slightly different fashions, one
store will be fuller than the other and originally time-synchronous samples
will be at different memory locations. To synchronise the two

35   machines, therefore, the excess data in the store of the leading
machine is delayed at time t_1 by a number of samples corresponding
to the difference 47 of the corresponding positions of the two
tapes. This may be done by telling the read address generator 21

of the faster machine to jump to a new address, leaving out the
excess data. The same result may be achieved, but with some
delay, by freezing the write address generator 20 for the number
of write cycles corresponding to the excess data.

During the subsequent period t_1 to t_3 where the tape
speeds of both machines continue to vary before stabilising to
the nominal speed, the operation of each machine is as described
earlier for fast start-up. Synchronism of the output data of the
two machines is guaranteed since they are both locked to the
common clock 41.

In order to perform these operations, there has to be some
common control over the two machines. A single control unit 25
may be provided for the two machines or a control unit of a master
machine may send jump instructions to the control unit of a slave
machine. By way of illustration, Fig 6 illustrates the former
alternative with the unit 25 connected to address generators 20a
and 21a of the second machine. There will also be connections to the
motor servo and store.

One specific technique for implementing the synchronisation
is as follows. The control unit 25 starts the two machines in
the manner described. Synchronisation is effected either a fixed
time (T_1 in Fig 1) after t_o or when the second of the up-to
speed signals on lines 44 and 44a is received. The control unit 25
then compares the states of fill of the two stores, which can be
done by comparing the corresponding signals REF and REFa. Then
a burst of pulses is emitted on a line 48 or 48a to jump on the
address generator 21 or 21a pertaining to the faster machine,
the number of pulse corresponding to the excess data in the store
of the faster machine. Thereafter the two machines complete the
start up routines as already described and then carry on with
normal replay.

Fast synchronisation may equally well be performed during
recording. In this case it is the slower machine which will have
excess data to be eliminated. This is again preferably effected
by jumping the read address generator of this machine.

It is always necessary to control one address generator of
a machine in accordance with tape speed. As already indicated the
information required for this may be fed back from the tape drive

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(tachometer 7) or be taken from an auxiliary time track played back from the tape.

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CLAIMS

1.   A method of effecting fast start-up of a recording or
replay operation of digital information on a magnetic tape having
a nominal tape speed range, characterised in that the tape is
accelerated so rapidly as to overshoot the nominal tape speed
5   range before stabilizing in that range, and in that recording on
to the tape from a digital store or replay from the tape into
the digital store is initiated substantially before the speed has
stabilized in the said range.

10   2.   A method according to claim 1, wherein the rate at which
digital information is transferred between the tape and the store
is controlled in dependence upon tape speed.

3.   A method according to claim 2, wherein the store is a random
15   access memory with a cyclic read address generator and a cyclic
write address generator, one address generator is clocked at a
fixed rate and the other is clocked at a rate corresponding to
tape speed.

20   4.   A method according to claim 3, wherein the read and write
addresses are compared to determine the degree of fill of the store
and, once the tape speed has stabilized, the tape speed is controlled
in dependence upon the degree of fill so as to tend to maintain
the degree of fill constant.
25

5.   A method according to any of claims 1 to 4, wherein the
recording on to the tape from the digital store or the replay
from the tape into the digital store is initiated substantially at
the time when the tape speed first reaches the nominal speed
30   range.

6.   A method according to any of claims 1 to 5, wherein,
during recording, writing of the digital information into the
store at a constant rate is initiated when acceleration of the
35   tape is commenced and read out from the store to the tape is
initiated substantially at the time when the tape speed first
reaches the nominal speed range.

7.   A method according to any of claims 1 to 5, wherein, during
replay, writing of the digital information into the store from
the tape and read out'from the store at a constant rate are both
initiated substantially at the time when the tape speed first

5   reaches the nominal speed range.

8.   A method according to any of claims 1 to 7, wherein two
tape machines are simultaneously started up and synchronized
by eliminating excess data from whichever store has filled more

10   than the other during the fast start-up.

9.   A method according to claim 8, wherein the synchronization by
elimination of excess data is effected substantially when the
slower machine first reaches the nominal tape speed range.

15

10.   A method according to claim 8 or 9, insofar as dependent on
claim 3, wherein the elimination of excess data is effected by
jumping the read address generator.

20   11.   Apparatus for carrying out the method according to claim 1,
comprising a tape machine, a store connected between record and
replay head(s) of the machine and input/output electronics for the
digital information, means for starting the machine in such a
way that the tape is accelerated so rapidly as to overshoot the

25   nominal tape speed range, and a control unit for initiating the
recording on to the tape from the digital store or the replay from
the tape into the digital address generator substantially at the
time when the tape speed first reaches the nominal speed range.

30   12.   Apparatus according to claim 11, wherein the store is a
random access memory with a cyclic read address generator and a
cyclic write address generator, and the control unit has a
record mode in which the write address generator is clocked at
a fixed rate while the read address generator is clocked in

35   dependence upon a signal representing tape speed, and a replay
mode in which the read address generator is clocked at a fixed
rate while the write address generator is clocked in dependence
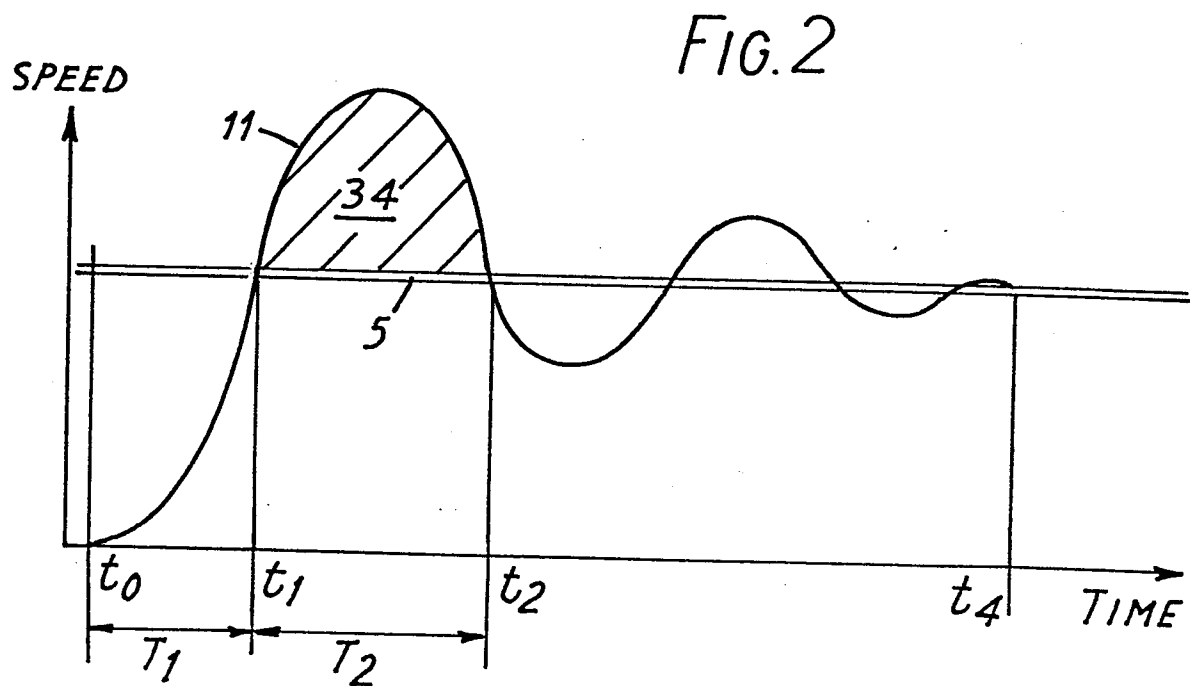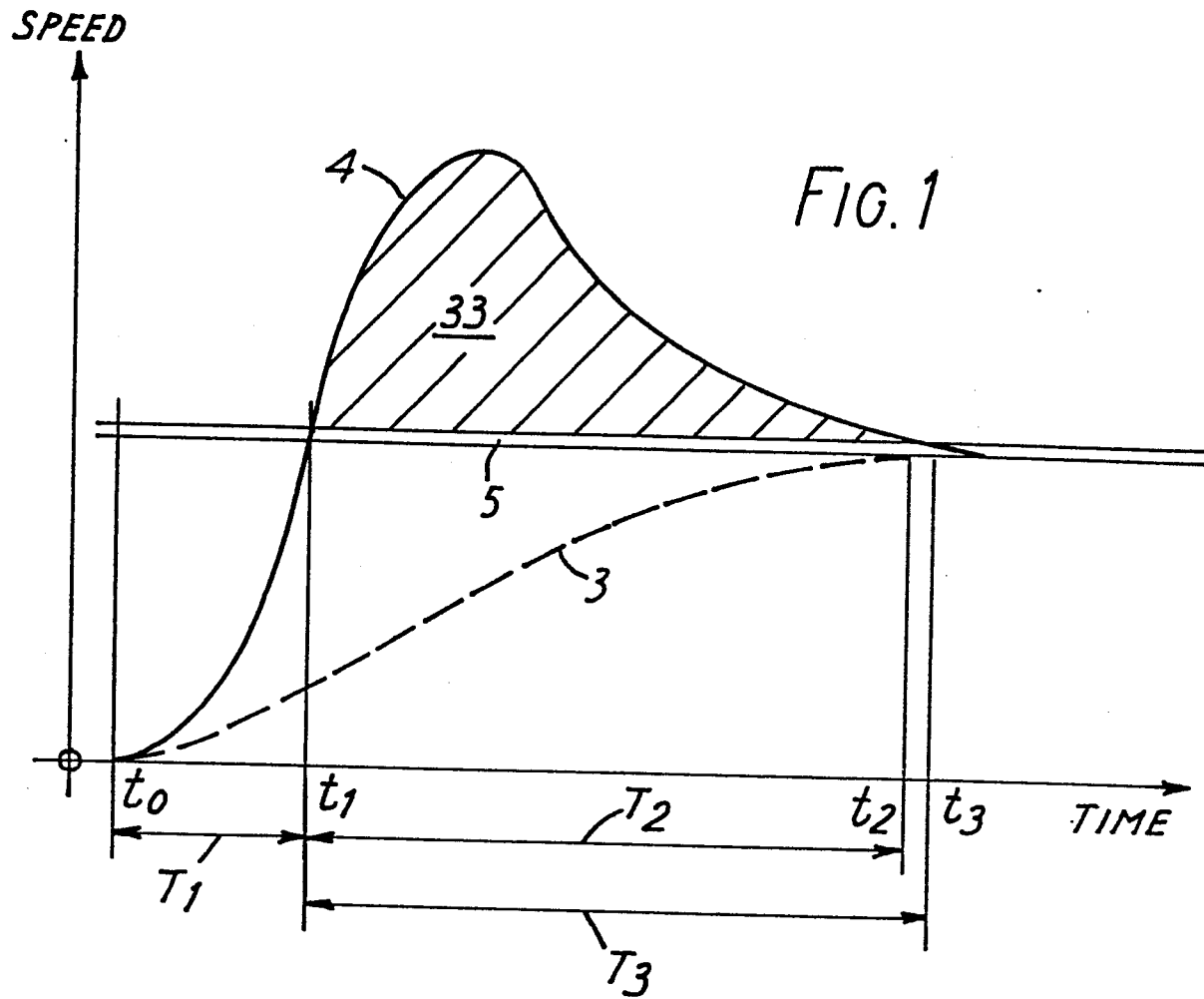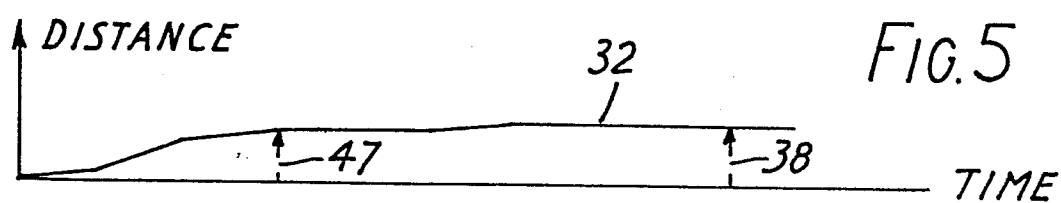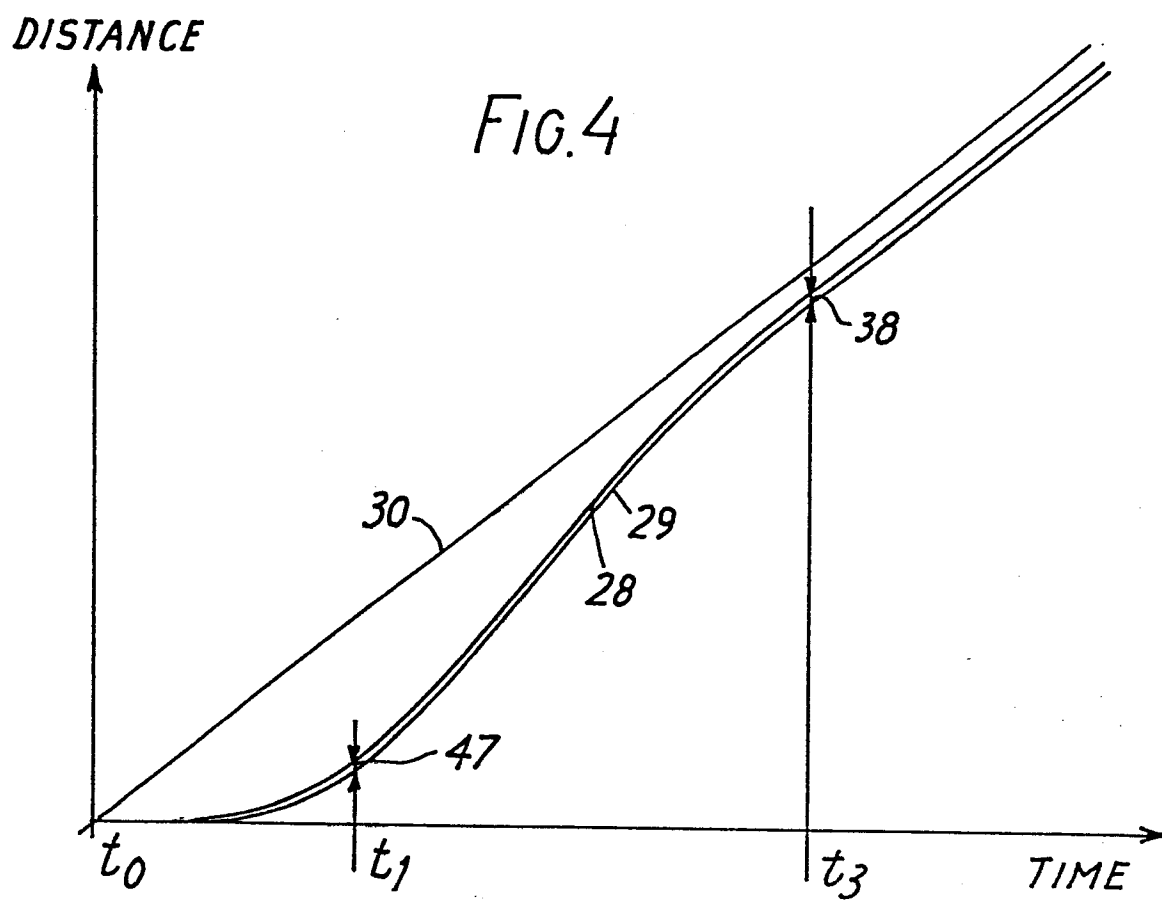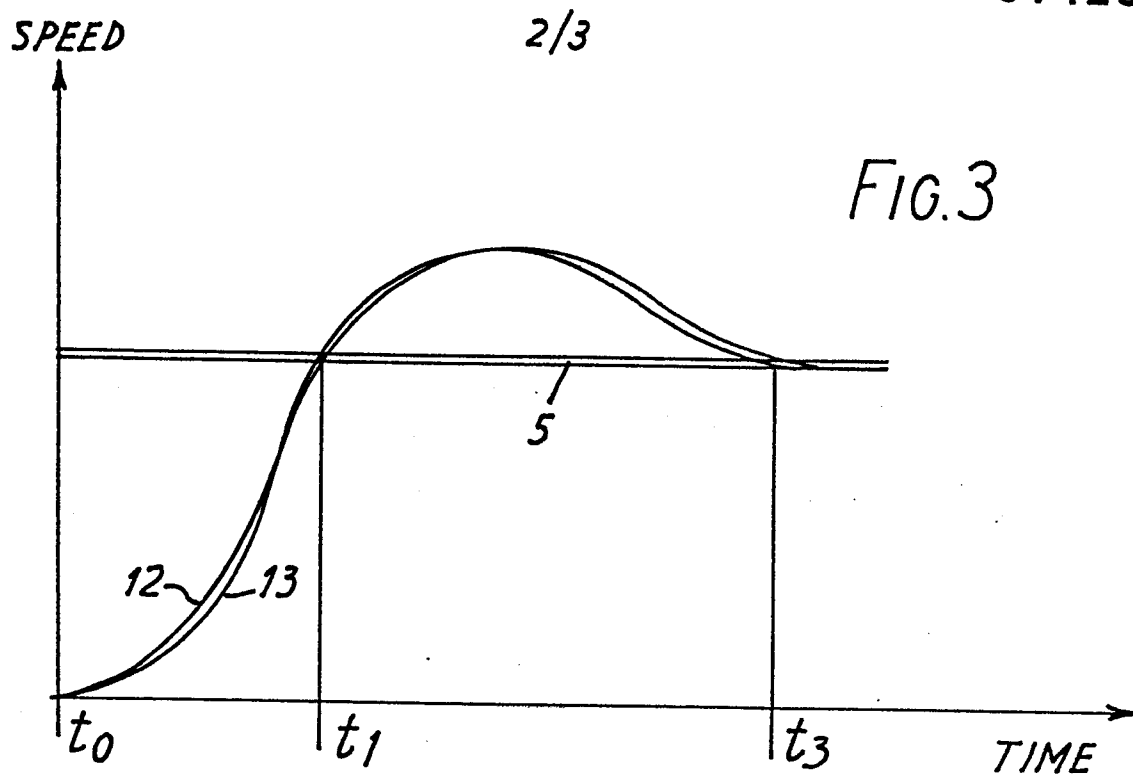upon the signal representing tape speed.

13.   Apparatus according to claim 12, comprising means for comparing the address provided by the two address generators and means for controlling the tape speed so as to tend to maintain the degree of fill of the store substantially constant.

5

14.   Apparatus according to claim 12 or 13, wherein two tape machines have a common control unit or linked control units adapted to jump the read address generator of one machine so as to bring the machines into synchronisation.

FIG.1

FIG.2

SPEED

FIG.3

5

12   13

t_0 t_1 t_3 TIME

DISTANCE

FIG.4

30
29
28

38

47

t_0 t_1 t_3 TIME

DISTANCE

32   FIG.5

47   38

TIME

FIG.6

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EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-A-2 639 895 (NIXDORF COMPUTER AG.) *Page 21, line 1 - page 29, line 27; figures 1,2*	1-4,6, 11,13	G 11 B 20/10 G 11 B 15/52 G 11 B 27/10 G 11 B 20/22

A	GB-A-1 133 879 (SCIENTIFIC DATA SYSTEMS INC.) *The whole document*	1,2,11	

A	US-A-3 491 341 (ALAIMO) *The whole document*	1,2,4, 6,11, 13	

A	US-A-4 398 227 (ANDERSON) *Column 5, line 50 - column 6, line 6; column 6, lines 18-32; column 11, lines 6-16*	1-3,6, 7,11	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
	---		G 11 B
A	GB-A-1 585 586 (THE SECRETARY OF STATE FOR DEFENCE) *Page 2, line 85 - page 3, line 86; page 4, lines 23-52*	1-4,8, 14	
	--- -/-		

	The present search report has been drawn up for all claims	
Place of search THE HAGUE	Date of completion of the search 05-12-1984	Examiner DAALMANS F.J.

European Patent
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EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT			Page 2
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 12, no. 7, December 1969, pages 1005-1006, New York (USA); F.H.KOST et al.: "Variable-velocity constant density magnetic tape recording". *The whole document*	1,8,14	
A	GB-A-2 089 094 (SONY CORPORATION)	8,14	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-12-1984	DAALMANS F.J.